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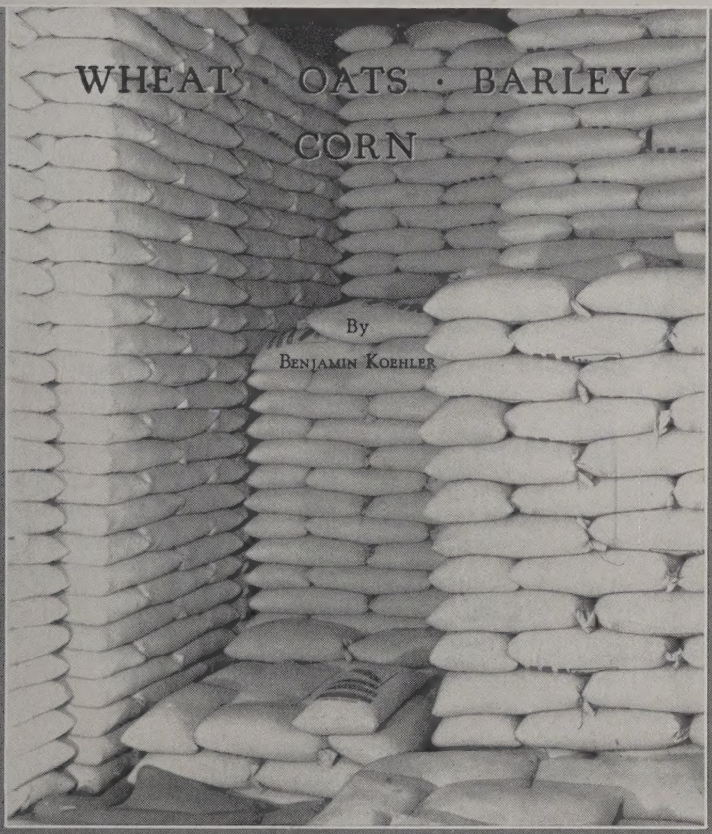
Effect of Storage on Yields of Farm Seed Treated for Disease Control



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Mercurial Seed Disinfectants Are Poisonous

The dust, therefore, should not be inhaled. If the treating cannot be done in an open place, a large suction fan should be installed in such a way that its action will be effective and a respirator should be worn over the nose and mouth to filter out some of the dust. The treated grain should never be fed to animals.

Urbana, Illinois April, 1941

Publications in the Bulletin series report the results of investigations made or sponsored by the Experiment Station

Effect of Storage on Yields of Farm Seed Treated for Disease Control

Wheat · Oats · Barley · Corn

By Benjamin Koehler, Chief in Crop Pathology

EXTENSIVE EMPLOYMENT of certain mercurial seed disinfectants and their proven worth for the control of some diseases of small grains, corn, and other crops have prompted experiments to determine the way in which these disinfectants can be used most effectively and economically. The experiments reported herein were conducted primarily with the object of determining what adjustments in the dosage of these mercurial disinfectants are needed when seed of wheat, oats, barley, or corn is to be stored for different lengths of time after it is treated and before it is planted. Data are also offered showing the effectiveness of certain copper compounds in controlling stinking smut of winter wheat and certain diseases of corn.

The results of these additional experiments with mercurial disinfectants lend emphasis to the recommendations made in Bulletin 420 of this Station, "Seed Treatments for the Control of Certain Diseases of Wheat, Oats, and Barley," published in 1935, and in Illinois Circular 444, "Seed Treatments for Farm Crops," published in 1936. In those publications it was stated that when seeds of small grains are to be stored for some weeks after they are treated with New Improved Ceresan (active ingredient, 5 percent ethyl mercury phosphate) better results are likely to be obtained by reducing the recommended dosage of ½ ounce per bushel to ¼ ounce.

The storage tests with seed corn included tests with grain of different moisture contents and with different conditions of storage.

The data from all the tests involving yields were analyzed statistically by the variance method, odds of 19 to 1 being used as the level for significance.

EXPERIMENTS WITH SMALL GRAINS

Method of Experimentation

Seed known to carry certain infections was obtained from several different sources. Lots that did not appear very clean were recleaned. Then each lot was thoroly mixed, and a 300-gram sample was taken

out for each different treatment and for the check. Treated samples to be stored were placed in small, loosely woven muslin bags that were made especially for the purpose. The small bags were buried in the center of a bushel of the same kind of grain similarly treated and held in a regular canvas grain sack tied shut. This procedure is important when testing the effect of storage, for it was shown (Table 3) that treatment is less effective when a 300-gram sample is stored by itself than when stored within a larger mass of treated grain.

All plantings were made in rod rows. A single row of seed from each treated lot and a check row were arranged at random in each block, and the blocks replicated sometimes 10 but usually 12 times.

The moisture content of all seed used in these experiments was less than 13 percent, and most of it was less than 12 percent. Seed taken from farmers' bins for treatment seldom shows more than 13 percent moisture unless the bin has received moisture from rain or the grain was combined too green. Even when small grain seed is not treated, experiments have shown that it is safest never to store it with a moisture content of more than 13 percent.[1]

Oats

Burt oats were obtained from a field showing about 5 percent of smutted heads. When used in the tests, the untreated checks developed only a trace of smut (Table 1), but the treated oats showed an increase in yield of 5 to 7 bushels an acre over the untreated checks. The increased yield from treatment may be due in part to the fact that even tho the smut in the untreated lot did not penetrate to the heads it nevertheless had some depressing effect on the yield. Iowar seed from another source, with heavier infection of both loose and covered smut, produced 6.3 percent smutty heads in the untreated rows in the tests and yielded 10 to 13 bushels more in the treated plots.

The oat seed used in these tests was treated by applying New Improved Ceresan at the rate of ½, ¼, and ⅛ ounce a bushel. Because of lack of smut development in the Burt oats, conclusions on smut control can be drawn only from the tests with Iowar oats. One-half ounce of New Improved Ceresan gave perfect smut control at storage periods of one day or less, but smaller dosages did not give perfect smut control in one day's time. After 23 days' storage ¼ ounce gave perfect smut control, and after 67 days' storage ⅛ ounce gave perfect control. Since the ⅛-ounce application gave better smut control after

[1]D. W. Robertson, A. M. Lute, and Robert Gardner. Effect of relative humidity on viability, moisture content, and respiration of wheat, oats, and barley seed in storage. Jour. Agr. Res. **59**, 281-292. 1939.

TABLE 1.—OATS: YIELD AND SMUT CONTROL WHEN SEED TREATED WITH NEW IMPROVED CERESAN[a] WAS STORED FOR VARIOUS PERIODS PRIOR TO PLANTING
(Experiment Station farm, Urbana, 1936)

Time seed was stored after treatment and before sowing	Bushel rate of applying treatment	Burt oats		Iowar oats		Average increase from seed treatment
		Smutty heads	Acre-yield	Smutty heads	Acre-yield	
days	*oz.*	*perct.*	*bu.*	*perct.*	*bu.*	*bu.*
Seed not treated	None	Trace	46.0	6.3	27.2	...
0	½	0	52.8	0	39.6	9.6
	¼	0	51.5	.5	38.7	8.5
	⅛	0	51.6	1.5	38.3	8.4
1	½	0	53.4	0	39.6	9.9
	¼	0	52.5	.4	39.7	9.5
	⅛	0	51.6	1.2	40.8	9.6
23	½	0	52.5	0	37.3	8.3
	¼	0	53.1	0	38.7	9.3
	⅛	0	53.6	.3	38.0	9.2
67	½	0	50.8	0	36.8	7.2
	¼	0	51.2	0	37.4	7.7
	⅛	0	53.9	.04	38.9	9.8
Difference[b] necessary for significance	...	...	3.2	...	2.5	...

[a]Active ingredient is ethyl mercury phosphate, 5 percent. [b]Difference between any two acre-yields.

67 days of storage than after 23 days (Table 1), there is good evidence that this material continues to act within stored grain for a long time. The use of as little as ⅛ ounce per bushel, however, does not seem advisable under actual farm conditions, for the mixing would not always be done so thoroly as it was in this test and the grain is not always recleaned. Dust and foreign matter may lower the effectiveness of some of the disinfectant.

The increases in the yield of the rows planted with treated seed over the yield of the rows of untreated seed are statistically significant in all tests. Furthermore, Iowar oats treated at the rate of ½ ounce of New Improved Ceresan per bushel yielded significantly less after 67 days' storage than after no storage or one day's storage. Some of the other differences are not significant. The trend of the data, however, leaves no doubt as to the preference of ½ ounce for short storage periods and ¼ ounce for longer periods. This conclusion is in agreement with results previously published in Bulletin 420, Tables 18 and 20.

Barley

Two varieties of spring barley from two sources were used for these tests—Wisconsin Pedigree 38, which carried very little infection in the seed; and Wisconsin Pedigree 5, which was somewhat dis-

TABLE 2.—BARLEY: YIELD WHEN SEED TREATED WITH NEW IMPROVED CERESAN WAS STORED FOR VARIOUS PERIODS PRIOR TO PLANTING
(Tests in Champaign and McHenry counties, 1936)

Time seed was stored after treatment and before sowing	Bushel rate of applying treatment	Acre-yields		Average increase from seed treatment
		Wisconsin Pedigree 5 (scab and blight infected)	Wisconsin Pedigree 38 (nearly disease-free)	
Experiment Station farm, Champaign county, central Illinois				
days	*oz.*	*bu.*	*bu.*	*bu.*
Seed not treated	None	14.8	23.6	...
0	½	22.0	26.3	5.0
	¼	21.3	25.3	4.1
30	½	20.4	22.5	2.3
	¼	22.5	25.7	4.9
Difference[a] necessary for significance	....	2.7	2.8	...
Ocock farm, McHenry county, northern Illinois				
Seed not treated	None	17.6	23.5	...
0	½	24.8	26.9	5.3
	¼	23.3	26.2	4.2
15	½	22.9	25.4	3.6
	¼	23.8	24.6	3.6
35	½	23.0	23.8	2.8
	¼	23.3	26.0	4.1
Difference[a] necessary for significance	....	1.9	2.1	...

[a]Difference between any two acre-yields.

colored by scab and blight. A laboratory test of the latter variety, using surface-sterilized seed, showed 11.8 percent Gibberella infection and 40.3 percent Helminthosporium infection.

Both varieties of barley were used in experiments in two locations, and the results in both locations agreed very well, as shown in Table 2. Even with seed that was nearly disease-free, seed treatment caused increases in yield that were statistically significant. Yields from untreated diseased seed were very low; increases resulting from seed treatment amounted to 6 to 7 bushels an acre.

When the seed was sowed on the same day that it was treated, ½ ounce of the disinfectant to a bushel of grain gave better yields than the ¼-ounce application; but the difference between the yields in each of the four individual tests was not large enough to be statistically significant, even with the severely diseased seed. Since, however, the trend was in the same direction in all four tests, the ½-ounce application is no doubt preferable when the seed is to be stored for two weeks

or less. When the seed was treated earlier and stored a month before it was sowed, ¼ ounce to a bushel gave better yields in every instance than did ½ ounce, and some of the differences in yields are statistically significant.

Wheat

For the wheat tests unusually smutty seed of a beardless variety was obtained from a grain elevator. It had a strong odor and was much discolored by the dark spores of stinking smut. It was recleaned

Grown from untreated seed Grown from treated seed

FIG. 1.—WINTER WHEAT GROWN FROM TREATED AND UNTREATED SEED

Note much heavier stand in the plot at the right. In some seasons seed treatment improves winter survival of wheat plants to a marked extent. Photograph was taken in April.

to remove foreign matter, some smut balls, and such smut spores as would readily blow off. This test provided a good opportunity to determine how reduced dosage of New Improved Ceresan (¼ ounce) would control an unusually heavy infection of stinking smut when the seed was held in storage for several weeks. It has already been shown (Bulletin 420, Table 16) that the regular dosage (½ ounce) reduced the yield of two varieties of wheat when the seed was subjected to prolonged storage.

Several copper compounds, as well as New Improved Ceresan, are entirely satisfactory for controlling stinking smut of wheat as well as for protecting the seed from soil infection (Fig. 1) and thus increasing the yield. Which disinfectant to use is therefore a matter of price

TABLE 3.—WINTER WHEAT: CONTROL OF STINKING SMUT AS RELATED TO KIND OF SEED TREATMENT, LENGTH OF TIME TREATED SEED WAS STORED PRIOR TO SOWING, AND DOSAGE OF NEW IMPROVED CERESAN
(Experiment Station farm, Urbana, 1938)

Seed treatment	Bushel rate of applying treatment	Time seed was stored after treatment and before sowing	Heads infested with stinking smut
	oz.	*days*	*perct.*
None	....	....	39.5
Copper carbonate, 50 percent copper (Corona)	2	1	.83
Basic copper sulfate, 50 percent copper (Basul)	2	1	Trace
Red copper oxid, 86 percent copper (Cuprocide)	1½	1	0
New Improved Ceresan	½	1	0
	½	17[a]	0
	¼	1	.67
	¼	17[b]	.52
	¼	17[a]	0

[a]Sample (300 grams of seed in loosely woven muslin bag) was buried in a bushel of wheat similarly treated. [b]Sample (300 grams of seed in loosely woven muslin bag) was stored by itself.

and personal preference. Since the copper compounds are nonvolatile they do not act during storage so long as the grain is kept dry. Hence, the length of time the grain is to be stored before it is seeded does not alter the required dosage of these compounds.

New Improved Ceresan used at the rate of ½ ounce to a bushel of seed stored one day, as well as ¼ ounce a bushel for the seed sample that was buried and stored 17 days, gave complete smut control (Table 3). It is seldom that Illinois farmers will want to treat seed as badly infected as was this lot, and it may therefore be safe to say that these rates of application are adequate when the seed has been recleaned. For less severely diseased seed these rates should be adequate even when the seed is not recleaned. When the treated seed was stored only one day or when it was stored for a longer time in very small quantity, ¼ ounce a bushel did not give complete control.

EXPERIMENTS WITH FIELD CORN

Disinfectants Used

Data from tests at the Experiment Station with corn planted between May 1 and 15 during the years 1926 to 1940 inclusive show that the better mercurial seed disinfectants have given an average annual increase in yield of 2 bushels per acre. Had as good disinfectants been available during the first half of this period as during the later years, the average increase would no doubt have been somewhat

Grown from treated seed Grown from untreated seed

FIG. 2.—CORN GROWN FROM TREATED AND UNTREATED SEED WITH INJURED SEED COATS

Unless the seed is treated, fungi from the soil enter thru the breaks in the seed coats and cause poor stands and reduced vigor.

higher. The benefits have varied greatly from year to year, the highest average annual increase being 5.7 bushels in 1935 and the lowest .2 bushel in 1927.[1] In individual experiments the range has been from an increase of 8.4 bushels to a decrease of 2.8 bushels. These data exclude all tests made with seed selected for a high degree of disease infection or injured seed coats, because in those tests the benefit from treatment was very much greater (Fig. 2 and Table 4).

As a rule when there has been cool weather after planting, seed treatment has caused better stands, stronger plants, and higher yields. On the other hand, seed treatments have not resulted in marked beneficial effects when germination and growth have been rapid as a result of warm weather and first-quality seed was used. As no one can predict weather conditions far enough in advance, it seems safest to treat all seed corn with a proper disinfectant, except possibly in the southern end of Illinois. Treatment will no doubt pay in an average year; and when spring growing conditions are adverse it is some insurance toward a satisfactory stand.

[1]Until 1937 these tests were conducted in cooperation with the U. S. Department of Agriculture. The results have been published in U. S. D. A. Cir. 34, Chemical-Dust Seed Treatments for Dent Corn, 1928; U. S. Dept. Agr. Tech. Bul. 260, Results of Seed-Treatment Experiments With Yellow Dent Corn, 1931; and Ill. Sta. and Ext. Cir. 484, Combating Corn Diseases in Illinois, 1938.

A large number of materials have been tested for their value as seed disinfectants for corn. Results from the most effective of those tested during the last four years are shown in Table 4.

The New Improved Ceresan was diluted with cornstarch so that it

TABLE 4.—CORN: EFFECT OF KIND OF SEED TREATMENT ON FIELD STAND AND YIELD OF GRAIN GROWN FROM INFECTED SEED, NEARLY DISEASE-FREE SEED, AND SEED ON WHICH THE COAT HAD BEEN INJURED

(All treatments applied one or two days before planting during first week of May, Experiment Station farm, Urbana, 1937-1940)

Condition of seed	Seed treatment	Field stand	Acre-yield	Increase in yield from treatment
	1937: Station strain Reid Yellow Dent			
		perct.	*bu.*	*bu.*
Sound seed coats, nearly disease-free	None	88.0	75.9	....
	New Improved Semesan Jr.[a]	90.5	78.2	2.3
	New Improved Ceresan diluted[b]	87.7	77.9	2.0
	Barbak-C[c]	92.7	77.8	1.9
	Cuprocide (red copper oxid)[d]	93.0	77.5	1.6
Injured seed coats, nearly disease-free	None	68.5	48.7	....
	New Improved Semesan Jr.	90.4	77.1	28.4*
	New Improved Ceresan diluted	90.7	76.0	27.3*
	Barbak-C	90.4	77.0	28.3*
	Cuprocide (red copper oxid)	92.3	78.2	29.5*
Sound seed coats, Diplodia infected	None	40.4	45.2	....
	New Improved Semesan Jr.	73.4	74.4	29.2*
	New Improved Ceresan diluted	75.3	74.7	29.5*
	Barbak-C	72.3	75.2	30.0*
	Cuprocide (red copper oxid)	60.8	62.7	17.5*
	1938: Illinois Hybrid 172			
Sound seed coats, nearly disease-free	None	84.6	86.3	....
	New Improved Semesan Jr.	85.3	88.0	1.7
	New Improved Ceresan diluted	84.7	87.5	1.2
	Barbak-C	89.0	90.8	4.5*
	Cuprocide (red copper oxid)	85.0	86.7	.4
Injured seed coats, nearly disease-free	None	62.2	71.6	....
	New Improved Semesan Jr.	64.3	79.2	7.6*
	New Improved Ceresan diluted	69.8	80.0	8.4*
	Barbak-C	78.0	84.8	13.2*
	Cuprocide (red copper oxid)	81.1	86.6	15.0*
	1938: Illinois Hybrid 498			
Diplodia infected	None	74.4	85.3	....
	New Improved Semesan Jr.	90.5	95.1	9.8*
	New Improved Ceresan diluted	88.1	96.7	11.4*
	Barbak-C	90.6	95.6	10.3*
	Cuprocide (red copper oxid)	89.3	95.3	10.0*
Gibberella infected	None	75.3	88.9	....
	New Improved Semesan Jr.	88.7	98.4	9.5*
	New Improved Ceresan diluted	89.3	99.0	10.1*
	Barbak-C	87.5	98.6	9.7*
	Cuprocide (red copper oxid)	84.7	96.6	7.7*

(*Table is concluded on page 267*)

TABLE 4.—EFFECT OF KIND OF SEED TREATMENT ON FIELD STAND AND YIELD OF CORN—*Concluded*

Condition of seed	Seed treatment	Field stand	Acre-yield	Increase in yield from treatment
	1939: Illinois Hybrid 960			
		perct.	*bu.*	*bu.*
Sound seed coats, nearly disease-free	None	97.0	90.7	....
	New Improved Semesan Jr.	97.8	92.9	2.2
	Barbak-C	95.6	91.6	.9
	Cuprocide (red copper oxid)	97.3	91.4	.7
	Yellow copper oxid[e]	96.8	89.6	−1.1
Injured seed coats, nearly disease-free	None	81.9	72.0	....
	New Improved Semesan Jr.	94.0	86.8	14.8*
	Barbak-C	93.5	83.7	11.7*
	Cuprocide (red copper oxid)	94.1	84.6	12.6*
	Yellow copper oxid	91.1	84.5	12.5*
Diplodia infected	None	47.7	46.3	....
	New Improved Semesan Jr.	77.8	65.1	18.8*
	Barbak-C	80.3	67.5	21.2*
	Cuprocide (red copper oxid)	72.9	60.3	14.0*
	Yellow copper oxid	71.5	63.2	16.9*
	1939: Station strain Reid Yellow Dent			
Diplodia infected	None	50.2	46.9	....
	New Improved Semesan Jr.	83.1	65.9	19.0*
	Barbak-C	81.5	66.6	19.7*
	Cuprocide (red copper oxid)	69.0	57.6	10.7*
	Yellow copper oxid	64.4	58.6	11.7*
	1940: Average for 5 commercial hybrids (U. S. 13 and Illinois 21, 784, 877, 960)			
Commercial seed similar to that sold to farmers	None	88.5	61.3	....
	New Improved Semesan Jr.	91.2	62.6	1.3
	Barbak-C	92.1	64.3	3.0*
	Sanoseed "65"[f]	91.5	63.2	1.9
	Cuprocide (red copper oxid)	90.7	60.7	−.6

*These increases in yield are statistically significant. [a]Active ingredient, 1 percent ethyl mercury phosphate. [b]In diluting the New Improved Ceresan with cornstarch, the active ingredient, 5 percent ethyl mercury phosphate, was reduced to 1 percent. [c]Active ingredients, 8 percent mercuric phenyl cyanamid and 2.5 percent cadmium oxid. [d]Used at the rate of 3 ounces per bushel in 1937 and 1938, and 2 ounces per bushel in 1939 and 1940. [e]Supplied by the makers of Cuprocide and theoretically differing from Cuprocide only in that the particles are still finer; used at the rate of 2 ounces per bushel. [f]Active ingredient, ethanol mercury chlorid not less than 1 percent.

contained the same percentage of ethyl mercury phosphate as New Improved Semesan Jr. Since the results from the diluted New Improved Ceresan were about equally as good as that from the New Improved Semesan Jr., there was a considerable saving in cost by using the diluted disinfectant. However, the thoro mixing of the cornstarch and the New Improved Ceresan cannot simply be done by hand with a paddle. In these experiments the dilution was prepared by filling a quart fruit jar one third full of a mixture of 1 part New

Improved Ceresan and 4 parts cornstarch. The jar was placed in a rotating machine turning at 40 r.p.m. and turned end to end for half an hour. A larger bulk of disinfectant would require a longer time for mixing, unless a better type of machine were used. Furthermore, the dilution cannot be resold.

The copper oxids are comparatively nonpoisonous and have given considerable promise as seed disinfectants. Red copper oxid ranked slightly better than other disinfectants tested for protecting the seed corn against infection from the soil when the seed coat was broken, but it ranked somewhat below some of the organic mercury disinfectants in controlling Diplodia seedling blight (Table 4). A disadvantage in the use of copper oxids is that they are somewhat cohesive and consequently the treated corn does not flow so readily as when it is not treated. This disadvantage can be overcome to some extent, however, by adding to each bushel of treated seed corn 1 ounce of extremely fine-flaked graphite specially prepared. Corn treated with red copper oxid has a reddish appearance; when the graphite is added the corn takes on a chocolate color.

Barbak-C and New Improved Semesan Jr. appear to be the best all-around disinfectants for seed corn now on the market and to be equally effective.

Method of Experimentation

Good-quality yellow-dent open-pollinated corn with a moisture content not over 12 percent was used except where otherwise indicated. The mercurial disinfectants were usually applied in a slight excess of the amounts needed and mixed with the seed in an experimental mixing machine.[1] The excess was then screened off. By weighing the dust added, as well as that screened off, it was found in certain tests that this method leaves about 1½ ounces of disinfectant on a bushel of seed. Other disinfectants were added by weighing the exact amount.

When seed was available in the ear, as it usually was, the seed composites for each plot replication were made up before the seed was treated. Most plots were 2 by 20 hills in size and planted 3 kernels to a hill. This required 120 kernels per plot. Thirty ears of corn were used, 4 kernels being taken from each ear for each plot. Replications ranged from 9 to 12 in different experiments.

When the experiment involved storage of the treated seed for some time before planting, paper envelops containing the same kind of treated seed were tied in a bundle and buried in a grain sack con-

[1]The mixing machine is illustrated and described in the Forty-Fourth Annual Report of the Illinois Agricultural Experiment Station (1930-31), page 56.

taining one bushel of corn similarly treated. The only exceptions had to do with: (1) the seed stored in an open shed, where the envelops were put into a box made of hardware cloth, and (2) the seed stored in sealed fruit jars. With the exception of the experiment involving the storage of treated seed in an open shed, all seed was stored in a closed seed house where the temperature was maintained at about 60° F. except when the outdoor temperature was warmer than that.

Seed Stored in Open Shed

Part of the seed treatments were made in February during the years 1931 to 1935 inclusive. The treated corn was stored in two places—in a moderately heated building and in a shed open at the sides. The corn stored in the open shed was placed close to the roof and thus thoroly protected against rain. Early in May, a day before planting, similar treatments were applied to additional kernels from the same seed ears. The crop of 1933 was lost because of drouth and chinch bugs. Results for the other four years are summarized in Table 5.

When Semesan Jr., Barbak III, and Merko were used as disinfectants, the treated seed stored in a heated building for three months gave, on the average, nearly the same results as the seed treated just before planting. The treated seed stored in an open shed, however, produced lower yields in nearly every case. All three of the materials

TABLE 5.—CORN: EFFECT OF STORAGE IN AN OPEN SHED AND IN A HEATED BUILDING ON YIELD OF OPEN-POLLINATED YELLOW-DENT CORN GROWN FROM SEED TREATED WITH MERCURIAL SEED DISINFECTANTS
(Experiment Station farm, Urbana, 1931-32 and 1934-35)

Seed treatment	Time between treatment and sowing	Place of storage	Increase per acre from seed treatment				
			1931	1932	1934	1935	Average
	days		*bu.*	*bu.*	*bu.*	*bu.*	*bu.*
Semesan Jr.[a]	1	Heated building	7.0*	3.4*	.3	5.0*	3.9*
	78–91	Heated building	7.4*	2.6*	−1.8	6.7*	3.7*
	78–91	Open shed	5.0*	1.7*	−3.0	.8	1.1
Barbak III[b]	1	Heated building	.4	3.6*	.7	4.9*	2.4*
	78–91	Heated building	2.9*	1.3	.9	4.5*	2.4*
	78–91	Open shed	.4	− .3	−1.6	− .8	− .6
Merko	1	Heated building	3.8*	.6	−2.4	3.2*	1.3
	78–91	Heated building	6.3*	3.2*	−3.3	3.5*	2.4
	78–91	Open shed	3.2*	1.2	−2.3	− .2	.5

*These increases in yield are statistically significant. [a]In 1931-32 the active ingredient in Semesan Jr. consisted of 12 percent hydroxymercuricresol; in 1934-35 it was 1 percent ethyl mercury phosphate and the name was changed to New Improved Semesan Jr. [b]Barbak III was a mercurial compound. It has now been replaced by Barbak-C, which has given better results. [c]Active ingredient of Merko is stated on the label merely as not less than 3.5 percent metallic mercury.

used contained mercury, but in different chemical combinations. If the seed stored in the open shed had been a larger quantity, the effect of its being out of doors probably would not have been so great. The data, however, demonstrate the need to store treated corn where it will be well protected from damp air.

Seed Stored for a Year

Each year in May, during the years 1934 to 1937 inclusive, a quantity of seed was treated with New Improved Semesan Jr. and then held over in the Agronomy seed house until the following May, when it was planted. Part of the same lot of seed was stored without treatment under the same conditions for the same length of time. The untreated seed was then divided into two lots: one was treated a day before planting, the other was planted without treatment.

The seed stored for a year after it was treated yielded an average of 3 bushels an acre more than the untreated check; while the seed that was not treated until a day before it was planted gave an increase of 3.3 bushels over the untreated check. Both increases are statistically significant, but the difference between them is not large enough to be significant. The seed treatment increased the yield in each case.

In view of the results obtained with small grains, showing that mercurial disinfectants continue to act during storage, it seems surprising that the seed corn stored for a year after treatment with a 1½-ounce application of New Improved Semesan Jr. was not injured by the disinfectant but produced nearly the same yields as the seed corn stored for only a day after the same application. As yet no satisfactory explanation can be given for this difference between treated seed of small grain and of corn.

Effect of Moisture Content of Seed

Corn stored in paper envelops.—In 1937 seed ears of two hybrids —Illinois 960 and another which was designated by a proprietary number —were field-selected and hanger-dried by the writer until the desired percentages of moisture in the grain were reached. Experiments were conducted with each.

At three intervals, each about a week apart, when the grain moisture was about 17, 15, and 12 percent respectively, some of the seed was placed in paper envelops with metal clasps. In order to keep the percentage of grain moisture constant, the envelops were put in sealed glass chambers containing about two gallons of air and were suspended over solutions of $CaCL_2$ at 19, 23, and 30 percent, creating relative humidities of 84, 79, and 70 percent respectively in these

chambers. Seed from each of the three moisture-groups was again divided into three lots, one treated with Barbak-C, another with New Improved Semesan Jr., and the third left untreated as a check.

All the seed was stored for slightly more than five months, each lot being put into a different container.

Of the seed stored at 17 percent moisture, the untreated checks were somewhat moldy with Penicillium when planted; the treated lots were not moldy. In the field plots planted from the seed with 17 percent moisture two results are worth noting: (1) the treated corn yielded better than the untreated; and (2) both the treated and the untreated seed gave a poorer field stand and a lower yield than that grown from seed stored at 15 and 12 percent moisture. On the other hand, the differences in field stand and yield between seed stored at 15 and at 12 percent moisture were not large enough to be statistically significant. Neither were the differences between results obtained with seed treated with Barbak-C and with New Improved Semesan Jr.

Corn stored in sealed jars.—In the preceding experiment the fumes from the disinfectants had more opportunity to dissipate than would likely be true in a large bulk of seed corn. Hence, in the fall of 1938 another test was made in a similar way except that part of the shelled grain was not put into paper envelops but was placed in quart glass jars filled nearly full and sealed air-tight. Seed from two hybrids—Illinois 960 and U. S. 13—was stored at two degrees of moisture, 15 percent and 12 percent. If the fumes of these disinfectants are really injurious to seed, these storage conditions would be expected to cause as severe damage as one might ever find in that moisture range under actual farm-storage conditions.

The seed corn that was stored at 15 percent moisture in sealed jars for 170 days yielded less than comparable lots of seed corn stored in paper envelops at 12 percent moisture and treated one day before sowing (Table 6). In the case of U. S. Hybrid 13 the average difference was statistically significant. Since it was shown by the experiment previously described that it made little difference whether seed corn was stored for one day or a year after treating it with similar dosages of mercurial disinfectant, the factor of time might be eliminated for the purpose of comparison. Whether the consistent reduction in yield with the seed stored at 15 percent moisture was due primarily to the effects of sealing or to the difference in moisture cannot be ascertained from the comparison. However, since the reduction in yields was as great with the untreated seed as with the treated, it would seem that the depressing effect on yields was not due to injury from the fumes caused by the action of moisture on the disinfectant.

TABLE 6.—CORN: EFFECT OF MOISTURE CONTENTS OF 15 AND 12 PERCENT UPON THE YIELDS OF CORN GROWN FROM SEED TREATED WITH MERCURIAL DISINFECTANTS AND STORED IN SEALED JARS FOR 170 DAYS AND FOR 1 DAY
(Experiment Station farm, Urbana, 1938-39)

Seed treatment	Time between treatment and sowing	Container for storing	Approximate grain moisture during storage	Acre-yield	
				U. S. Hybrid 13	Illinois Hybrid 960
	days		*perct.*	*bu.*	*bu.*
None	...	Paper envelop	12	74.1	76.2
Barbak-C	1	Paper envelop	12	76.0	77.5
New Improved Semesan Jr.	1	Paper envelop	12	76.0	77.3
None	...	Sealed jar	12	71.8	75.1
Barbak-C	170	Sealed jar	12	75.2	76.6
New Improved Semesan Jr.	170	Sealed jar	12	74.5	77.1
None	...	Sealed jar	15	68.2	73.7
Barbak-C	170	Sealed jar	15	72.8	75.3
New Improved Semesan Jr.	170	Sealed jar	15	71.6	76.2
Difference[a] necessary for significance	...	.....	...	3.4	4.1

[a]Difference between any two yields.

The seed stored in sealed jars for 170 days at 15 percent moisture yielded consistently less than comparable lots which were stored at 12 percent moisture also in sealed jars and for the same length of time. Altho only one of the differences was significant, the data strongly indicate that higher moisture percentage caused a reduction in yield. Since, as before, the reduction was as great with the untreated seed as with the treated, it would seem that the difference in yield was due to the effect of the higher moisture alone and not to the treatment and the moisture acting together.

If the temperature had been warmer during the storage period, the damage from storing the corn at 15 percent moisture would probably have been greater. Regardless of whether stored seed is treated or not, temperature as well as moisture percentage and length of storage is a factor in the longevity of the seed.[1] Thus, even tho the differences in yield between the corn grown from seed stored at 15 percent and at 12 percent moisture were not large, 15 percent would probably be dangerously high when seed is stored in a large bulk for a considerable time.

SUMMARY

The organic mercury disinfectants used in the experiments reported herein were for the most part those being sold widely for seed treat-

[1]E. H. Toole. Seed longevity and seed storage. Mimeo. report, U. S. Department of Agriculture, Beltsville, Md. 1939.

ment. In addition, tests on wheat and seed corn were made with some copper compounds which, compared with the mercury disinfectants, are relatively nonpoisonous to humans.

Test samples of treated grain stored for more than a few days were usually placed in the center of a bushel lot of the same kind of grain similarly treated. The action of the treatment was shown to be stronger when the seed was stored in this way than when it was put in small cloth sacks or envelops and not surrounded by treated grain.

Wheat, oats, barley.—New Improved Ceresan, a mercurial disinfectant, was applied to wheat, oat, and barley seed in dosages of ½ and ¼ ounce a bushel, and in some cases in a dosage of ⅛ ounce. The treated seed was stored for periods varying from several hours to 67 days. All this seed had a moisture content of less than 13 percent while in storage. One-fourth ounce of the disinfectant applied two or more weeks before sowing gave as good disease control and as good or better yields of grain as ½ ounce applied one day before sowing. The diseases studied were loose and covered smuts of oats, scab and blight of barley, and stinking smut of wheat.

Stinking smut of wheat was also controlled successfully by treating the seed with any of the following materials at the bushel rates indicated: 2 ounces of copper carbonate, 2 ounces of basic copper oxid, or 1½ ounces of red copper oxid.

Corn.—Several types of experiments with treated corn were conducted during the last nine years to determine the effects of different storage conditions on subsequent yields of the planted seed. Lots of seed were stored in a moderately heated building while other lots were stored in an open shed. Some seed was sealed air-tight in quart jars. Several organic mercury disinfectants were applied. Only one rate of application, about 1½ ounces a bushel, was used, but the periods of storage ranged from one day to one year. Some of the treated corn was stored with moisture contents of 17, 15, and 12 percent.

Contrary to results with seed of small grain, seed corn was not injured when the same rate of mercurial disinfectant was applied one year before sowing as was applied when the seed was treated and stored for one day. Corn grown from seed stored at 17 and at 15 percent moisture produced yields inferior to corn grown from seed stored at 12 percent moisture. Since this was true whether the seed was treated or untreated, the difference in yield was apparently not due to the combined action of the moisture and the disinfectant but to the effect of the moisture alone.

New Improved Ceresan, when reduced to 1 percent ethyl mercury

phosphate with cornstarch, gave results similar to those obtained with New Improved Semesan Jr.

Red copper oxid ranked slightly better than other disinfectants tested for protecting seed corn against infection from the soil when the seed coat was broken, but it ranked somewhat below some organic mercury disinfectants in controlling Diplodia seedling blight.

RECOMMENDATIONS

The recommendations formulated here are based mainly on the tests reported in this bulletin, tho experimental work previously reported by the author and others has also been drawn upon in order to make the recommendations of more practical value.

Small grains. Whether treated or untreated, small grains stored for seed purposes should not contain more than 13 percent moisture, and preferably not over 12 percent.

New Improved Ceresan is recommended for the treatment of wheat, oat, and barley seed. To avoid possible damage to the seed, only ¼ ounce of this disinfectant (instead of ½ ounce) should be used when the seed is to be stored for two weeks or more. The Illinois tests repeatedly demonstrated that ¼ ounce applied two weeks before seeding is just as effective for controlling seed-borne smut infection as ½ ounce applied one day before seeding. With longer storage periods, the disinfectant was found to be still more potent.

It is probable, however, that the reduced dosage of New Improved Ceresan will be less effective for stopping infection originating in the soil; nevertheless treated seed stored two or more weeks usually showed better yields under the ¼-ounce application than under the ½-ounce.

There is one exception to the recommendation of a ¼-ounce application of New Improved Ceresan. When wheat is darkly colored by smut and the grain is not recleaned before it is treated, ½ ounce will be necessary even if the disinfectant is applied several weeks in advance of planting, and as much as a full ounce will be needed if it is applied a day or two before seeding. However, wheat so badly infected is unusual and seldom is used for seed purposes.

Copper carbonate, basic copper sulfate (as sold under the trade name of Basul), and red copper oxid (as sold under the trade name of Cuprocide) are nonvolatile compounds and give good control of seed-borne diseases of wheat. These treatments are also effective in controlling seed-borne diseases in hull-less oats and barley but not in the kind of oats and barley most widely grown in Illinois. Because

these disinfectants are nonvolatile they produce no action during storage. Thus the full dosage must be applied whether the grain is to be seeded immediately or stored for a long time. The recommended dosages are: 2 to 3 ounces for copper carbonate, 2 ounces for basic copper sulfate, and 1½ ounces for red copper oxid. While these copper compounds are considerably less poisonous to humans than the mercury compounds, anyone using them should protect himself from the dust or his nose and throat will become irritated.

Use of custom seed-cleaning machines.—Twenty-seven or more custom seed-cleaning machines were in active use in Illinois in 1940 and handled more than 400,000 bushels of seed grain. Most of this work is done more than two weeks before the seed is planted. As these machines are equipped with seed treaters, the cost of applying ¼ ounce of New Improved Ceresan is very small.

It has been well demonstrated that the practice of systematically treating wheat, oat, and barley seed before planting will return, several times over, the entire cost of both cleaning and treating if the disinfectant is properly applied and is not applied in excessive amounts. There are other seed-borne diseases besides smut that can be eliminated in this way. Scab and Helminthosporium blight in wheat and barley, and stripe disease in barley need to be controlled. There is also seed-

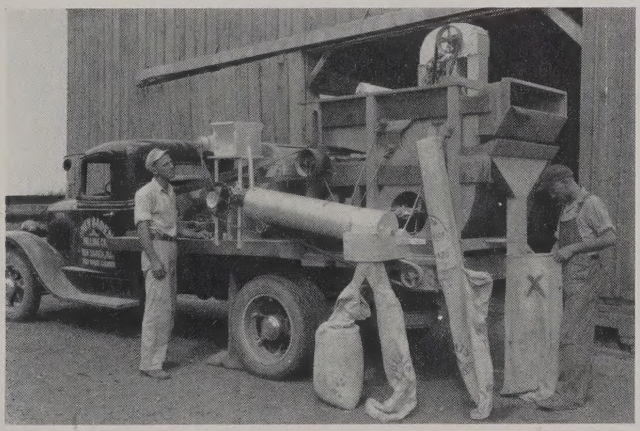

FIG. 3.—PORTABLE SEED CLEANER AND TREATER

Machines such as this are doing much to improve the quality of small-grain seed planted in Illinois. Because the machines make a circuit of many farms, some of the treating must be done months before sowing time, and the treated seed stored.

ling blight in wheat, oats, and barley that results from organisms present in the soil. Indeed it is the exception, rather than the rule, for a crop to escape without being injured by infection with some one or several of such organisms when the seed has not been treated.

Systematic treatment of seed grain every year with lower dosages of disinfectant is better than an occasional treatment with larger dosages, for regular treatment means no danger to the seed and practical freedom from those diseases that are amenable to control by seed treatment. Furthermore, the cost is almost negligible when only ¼ ounce of disinfectant per bushel is used.

Corn. The disinfectants sold under the trade names of New Improved Semesan Jr. and Barbak-C can be recommended for the control of seedling diseases of corn. The active ingredients of these materials are mercurial compounds and are somewhat volatile in nature. Seed corn can be safely treated with either of these disinfectants and stored for six months to a year before it is planted, provided the moisture content is not too high and the seed is protected against high atmospheric humidity by being stored in a tightly closed building. Heating the building slightly from late fall until spring would probably be advantageous.

Perhaps no exact recommendation can be made with regard to the moisture limit that is safe. The length of time the seed is stored and the temperature during storage have an important bearing on the safe moisture percentage, and there may be other modifying factors. In the experiments herein reported 15 percent was too high. Even 14 percent would probably be risky under some conditions.

It is also important that the application of mercurial disinfectants never be in excess of an amount that will adhere to the seed corn. This will usually be about 1½ ounces a bushel. The application should be carefully regulated or else the treated grain should be run over a sieve to remove all excess disinfectant.

Directions for applying all the seed treatments included in these recommendations are given in Circular 444 of this Station entitled "Seed Treatments for Farm Crops."

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